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(56) Documents Cited
GB 2017593 A GB 2017592 A GB 2001012 A
GB 1546976 A GB 1233422 A US 4202648 A

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(54) **Storage of production fluids from undersea oil deposits or reservoirs**

(57) A vessel (20) equipped for storage of oil production fluids from an undersea reservoir comprising at least one storage tank (25) and a superstructure (not shown) which is supported by a plurality of downwardly extending legs (21). The legs and superstructure are connected together to form a buoyant structure. The or each said storage tank (25) is fixed to the vessel such that, in use, the or each storage tank is submerged below the sea surface. The storage tank means is provided with insulating means for reducing heat loss from oil production fluids stored therein.

The or each said storage tank is preferably arranged to receive and discharge oil production fluids and sea water such that in one use condition thereof, the storage tank is filled with a liquid consisting of two separate substantially co-extensive layers with such oil production fluids floating on sea water.

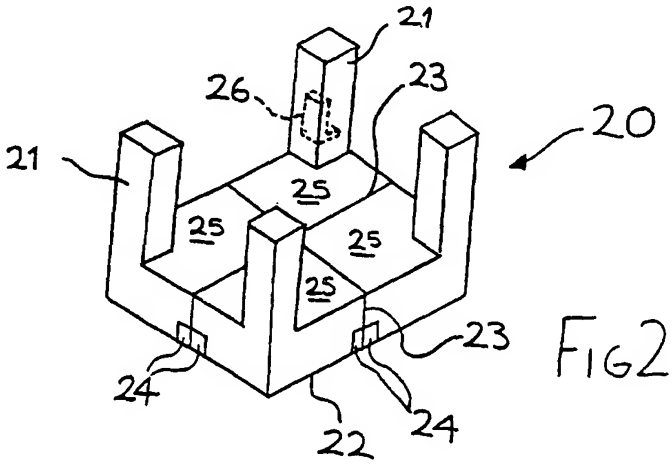

FIG2

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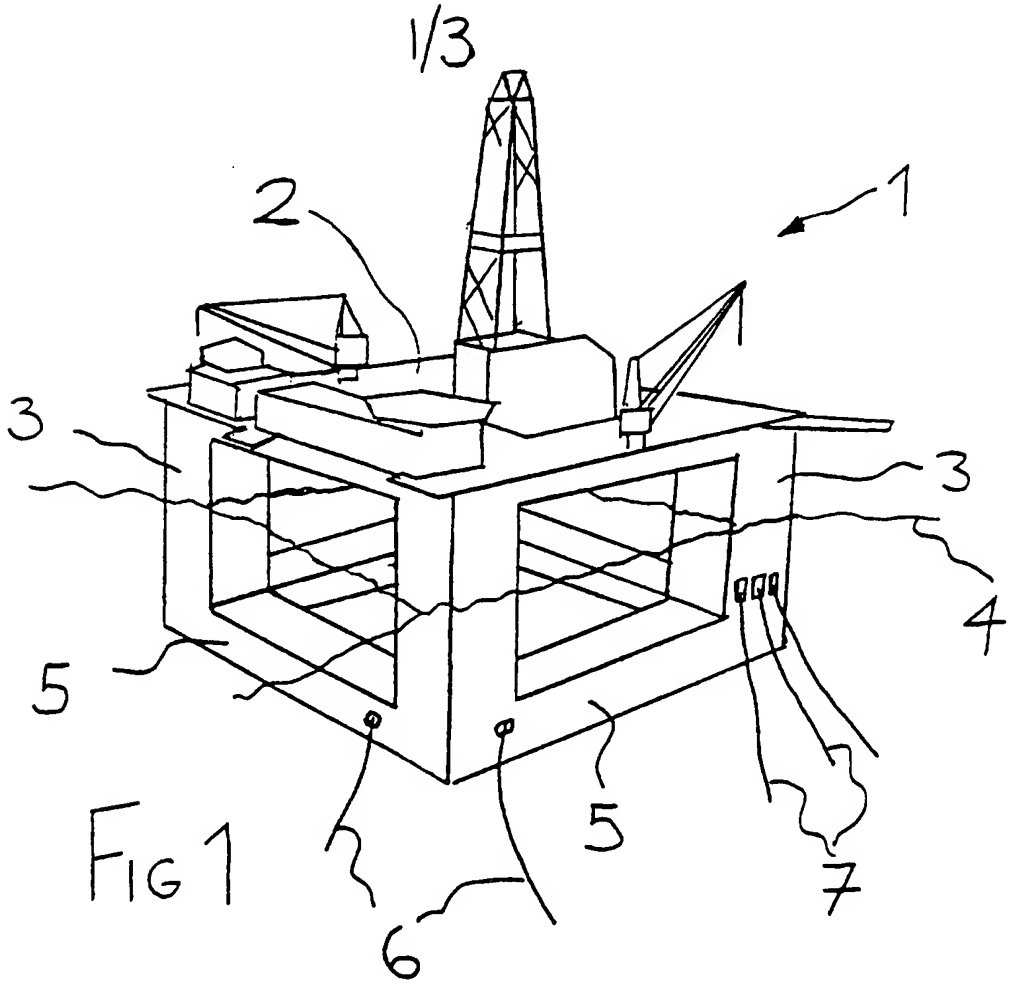


FIG 1

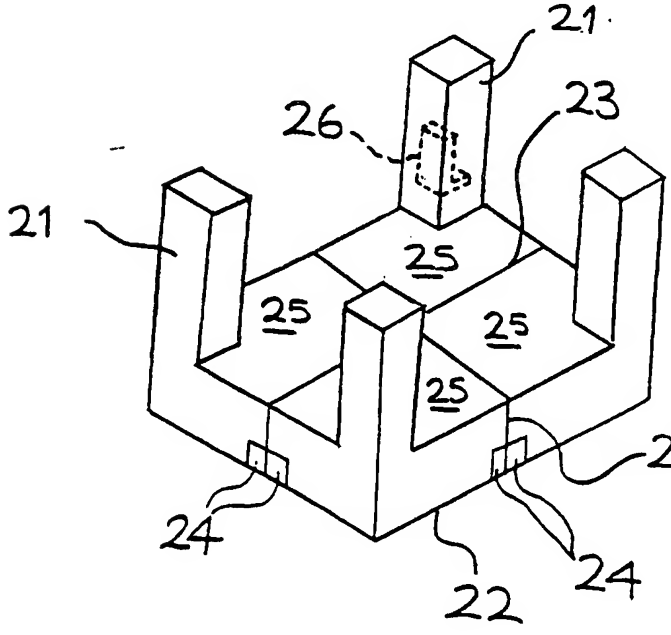


FIG 2

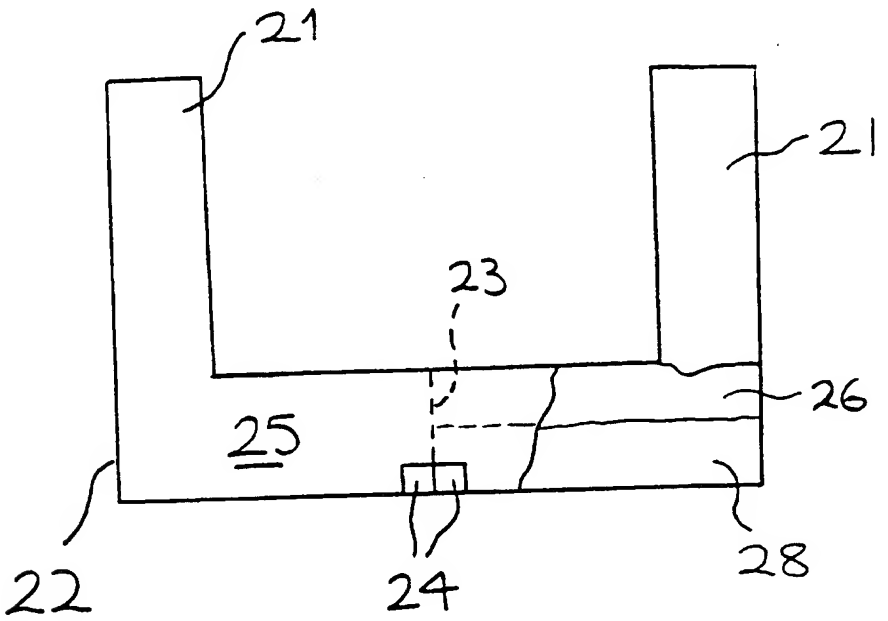


FIG 3

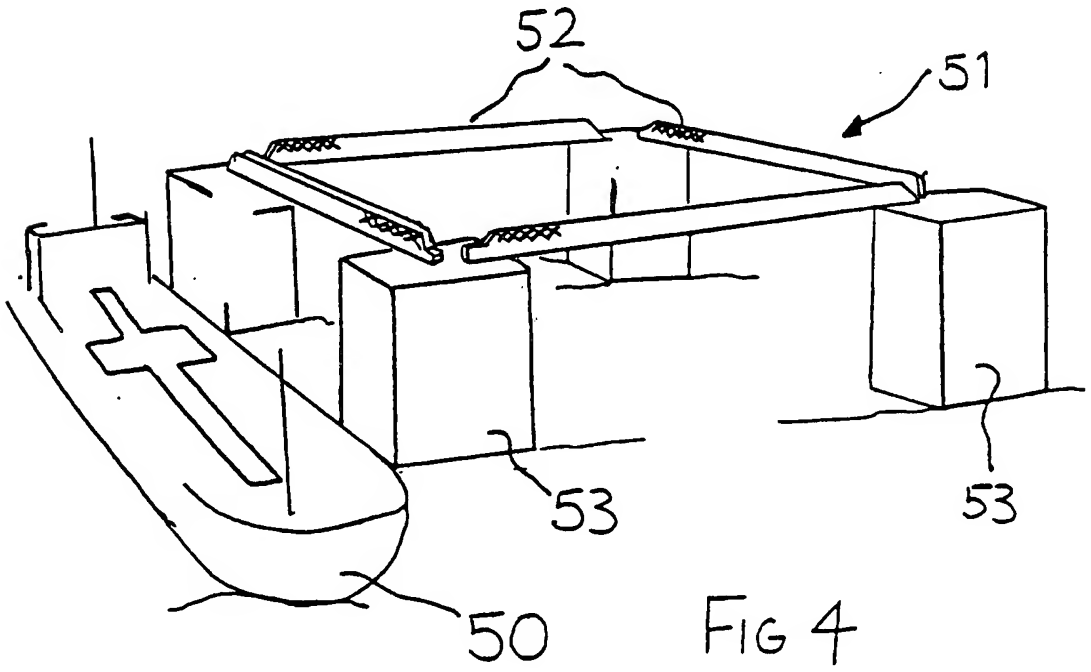
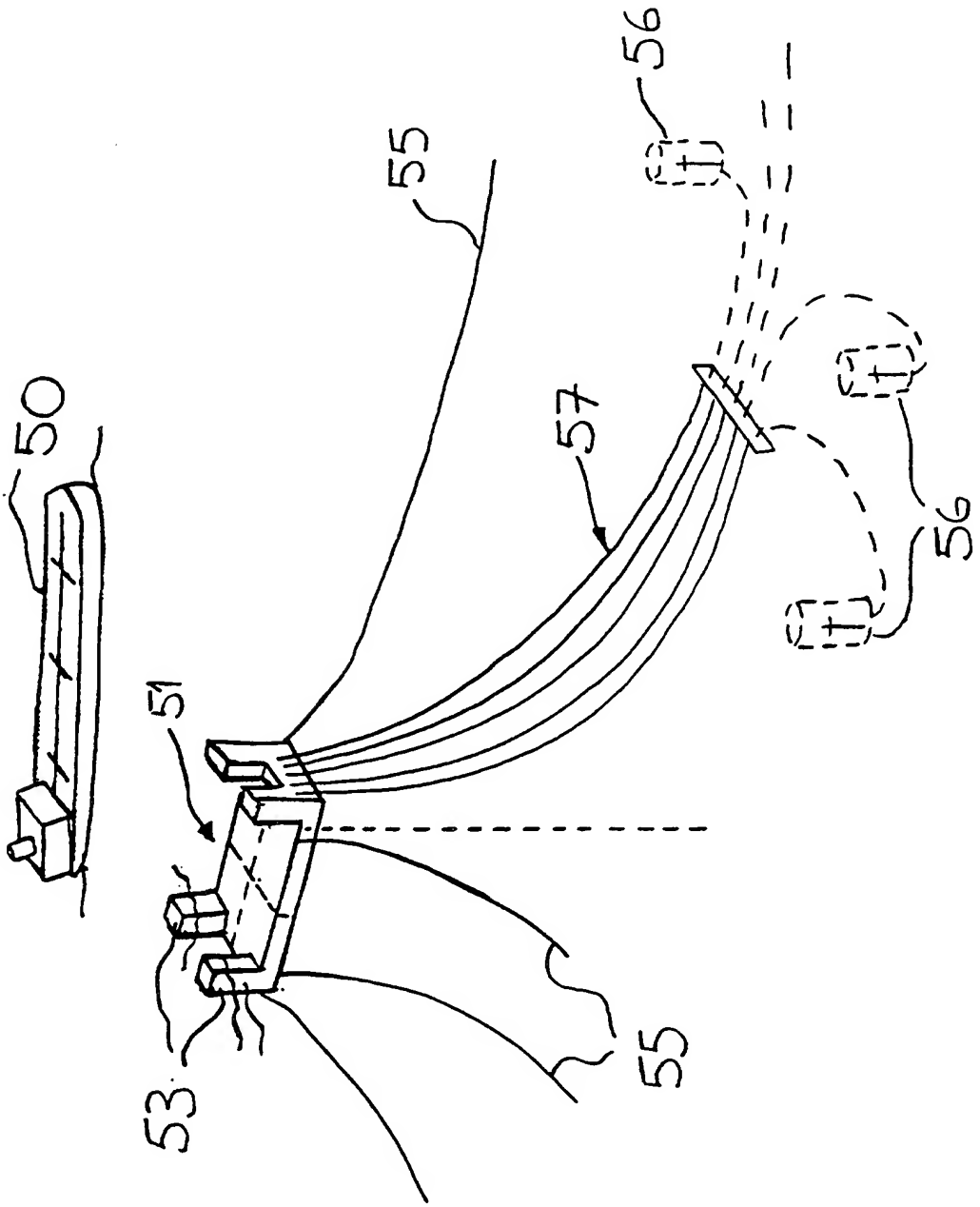


FIG 4

FIG 5



STORAGE OF PRODUCTION FLUIDS FROM UNDERSEA OIL DEPOSITS OR RESERVOIRS

The invention relates to storage of production fluids from undersea oil deposits or reservoirs. The invention relates particularly, though not exclusively, to the storage of significant quantities of production fluids prior to transport to shore.

Undersea oil or gas deposits are extracted using offshore floating platforms or semi-submersibles. Conventional semi-submersibles generally comprise a superstructure supported by four buoyant legs which extend below the surface of the water. These floating platforms are secured to the seabed by a plurality of fixed mooring lines. Oil extracted from below the sea bed is pumped from the wellhead to the surface via flexible or semi-riding pipes known as "risers". The produced fluids are then pumped to a ship or shuttle tanker for transport to a shore-based oil refinery or storage unit. Conventional semi-submersible platforms have no oil storage facilities, or only very limited oil storage facilities.

In order to ensure optimum production of fluids from the well, it is necessary to provide means of transporting oil from the well on a regular basis. This is relatively easy for oil wells situated only a short distance from a shore-based oil refinery or

storage unit. However, as near-shore oil reserves are exhausted there is a need to be able to exploit undersea oil deposits profitably in more remote and hostile environments. Servicing such wells with tankers would be expensive and any delay in journey time can result in long period where well fluids cannot be produced. Delays are more likely due to the remote location and nature of the environment. Profitability is likely to be significantly reduced for these wells.

Furthermore, in some environments it is necessary for the production platform to be moved away from the undersea oil deposit or reservoir. Examples of circumstances where it might be necessary to move a platform might include imminent adverse weather conditions, or possibly to avoid large icebergs which might otherwise damage the production platform. This halts production of fluids completely and a tanker will either have to wait until production can be resumed or return only partially loaded.

Referring to Figure 1 a known type of semi-submersible, generally indicated by reference numeral 1, comprises a superstructure 2, and four buoyant legs 3 extending downward into the sea 4. The ends of adjacent legs are connected by structural members 5 to increase rigidity. The semi-submersible is secured to

the seabed by mooring lines 6. Well fluids are pumped from the well head to the surface via a series of flexible or semi-rigid risers 7. This known type of semi-submersible is provided with very limited oil storage capacity in tanks located in the legs 3.

The invention seeks to overcome disadvantages associated with known techniques of extracting oil or hydrocarbon deposits by providing storage for quantities of produced fluids prior to transport to shore.

The invention provides a vessel equipped for storage of oil production fluids from an undersea reservoir, said vessel comprising storage tank means and a superstructure which is supported by downwardly extending leg means, said superstructure and leg means being connected together to form a buoyant structure and said storage tank means being fixed to the vessel such that, in use, the storage tank means is submerged below the sea surface, said storage tank means being provided with insulating means for reducing heat loss from oil production fluids stored therein.

The storage tank means may be lined with an insulating material.

In cold water some oils or produced fluids solidify or become very viscous. This makes pumping fluids to a shuttle tanker very difficult. Insulation

reduces the rate of heat loss and helps to maintain the oil or produced fluids in a lower viscosity state.

The vessel can store significant quantities of production fluids compared with known oil production platforms or barges. In use the or each submerged storage tank is filled with liquid at all times i.e. with (i) sea water alone; (ii) production fluids alone; or (iii) a liquid consisting production fluids and sea water in two separate coextensive layers with the production fluids floating on the sea water. When production fluids are pumped from such a storage tank to a tanker, the tank is emptied of produced fluids and progressively filled, via any suitable inlet means to the tank, with sea water. The produced fluids in a partially emptied storage tank float on top of the rising level of sea water in the tank. This has the advantage that the change in draft of the vessel is minimal as the storage tank is filled or emptied (because of the similar densities of oil and sea water). This overcomes problems associated with the vessel rising up out of the water as oil is transferred to a tanker. With storage tanks fixed to an oil platform above the surface of the sea (in known structures) the change in draft is considerable and this means that surface oil storage tanks have to have a very limited capacity. Large changes in draft not

only cause problems in transferring oil but can also place significant strain on the semi-submersible mooring lines. Furthermore, storage tanks located above, or partially above, water must be designed to be able to withstand a combination of the internal pressure caused by the volume of fluid in the tank plus any environmental factors such as wave and wind pressure, plus a safety factor. Consequently tanks situated above water level, either fixed to the superstructure or located in the legs, must have an extremely strong structure. Normally this would involve using thick plate sections to avoid deformation. This is prohibitively expensive and also raises the centre of gravity of the whole structure which adds a factor of instability to the structure and is clearly undesirable. By submerging the tanks below water level, factors such as wind and wave pressure are eliminated and the structure of the tank can be made much lighter because pressure differentials across the tank walls are virtually eliminated. A further advantage is that safety is significantly enhanced as the storage tank is surrounded by sea water and contact with air is eliminated thereby reducing the risk of explosion or fire if a leak were to form in the tank wall, or if the tank ruptured.

Preferably, the or each storage tank is provided with insulating means for reducing heat loss from oil production fluids stored therein. The or each storage tank may be lined with an insulating material.

Furthermore, the insulation can provide increased protection against leakage of oil into the surrounding environment.

Preferably, the or each said storage tank is fixed to the lower ends of said legs.

This places the storage tank well below the water surface and eliminates wave pressure effects on the tank walls. Placing the tank in this position also lowers the centre of gravity of the vessel's structure and produces an inherently more stable vessel capable of withstanding more adverse weather conditions.

Preferably, the or each said storage tank is integrally connected to the lower ends of said legs. This construction of vessel produces a rigid structure and eliminates the need to provide additional supports between the legs.

The vessel may comprise a body defining a plurality of said storage tanks, said legs being connected with the body.

The body may be provided with two substantially perpendicular partitions which define four said storage tanks, each said storage tank being provided

with a respective flow port for (i) admission of sea water during pumping out of oil production fluids stored therein and (ii) discharge of sea water during filling of the storage tank with oil production fluids.

The partitions increase structural strength and rigidity and permit a larger volume of produced fluids to be stored in the body.

The vessel may comprise monitoring means for monitoring the presence of such oil production produced fluids in sea water expelled from the or each said storage tank during filling with such oil production fluids.

The monitoring means prevents produced fluids from being expelled into the surrounding sea thereby preventing environmental damage.

The monitoring means may comprise at least one settling tank for removing such oil production fluids from sea water when the latter is discharged from the or each said storage tank.

The legs may be provided with buoyancy tanks for allowing the buoyancy of the vessel to be altered.

Although the density of sea water and oil is similar, there is a small difference which produces a small change in draft of the vessel as the storage tank or tanks is/are filled or emptied. The filling

or emptying of the buoyancy tanks in the legs may be controlled to compensate for this small change in draft of the vessel. This eliminates any additional strain that might be placed on the moorings caused by the vessel rising out of the water.

The vessel may be substantially constructed from square or rectangular box sections butt-welded together.

This construction of vessel uses ship-building principles to produce a strong and cost effective structure. This type of structure eliminates the need to use rounded cross-section legs and their complicated connecting sections at the bottom corners of the vessel.

The or each storage tank may be provided with membrane means for separating said layers of oil production fluids and sea water.

The invention also includes a method of storing oil production fluids in an oil production vessel having a submerged storage tank fixed to buoyant support legs of the vessel, said method comprising (i) filling the submerged tank with sea water and (ii) pumping oil production fluids into the storage tank and causing or allowing sea water in the storage tank to be discharged as said oil production fluids are pumped into the storage tank such that said oil

production fluids, being of lower density than sea water, float as a layer on the sea water whereby the storage tank is filled by a liquid consisting of a layer of sea water and a separate substantially coextensive layer of oil production fluids.

Preferably, collection means is provided to receive the displaced sea water which is discharged from the storage tank and separate any oil production fluids present in the sea water prior to the sea water being expelled into the surrounding environment.

The collection means may include a settling tank which helps maintain separation of sea water and oil production fluids. The separated oil production fluids may be returned to the storage tank.

The method may include the step of providing membrane means in said storage tank for separating said layers of oil production fluids and sea water.

The invention also includes a semi-submersible production platform comprising at least one storage tank for receiving and storing production fluids and a superstructure supported by a plurality of downwardly extending legs, said legs and superstructure being connected together to form a buoyant structure and the or each said storage tank being arranged to be submerged below the sea surface, in use, and being provided with at least one flow port

for (i) admitting sea water into the storage tank to compensate for production fluids being discharged therefrom and (ii) for allowing sea water in the storage tank to be discharged during filling thereof with production fluids, whereby in one use condition thereof the or each said storage tank is filled with a liquid consisting of two separate substantially coextensive layers with the production fluids floating on sea water.

The invention also includes a semi-submersible barge comprising at least one storage tank for receiving and storing production fluids and a superstructure supported by a plurality of downwardly extending legs, said legs and said superstructure being connected together to form a buoyant structure and the or each said storage tank being arranged to be submerged below the sea surface, in use, and being provided with at least one flow port for (i) admitting sea water into the storage tank to compensate for production fluids being discharged therefrom and (ii) for allowing sea water in the storage tank to be discharged during filling of the storage tank with production fluids, whereby in one use condition thereof the or each said storage tank is filled with a liquid consisting of two separate substantially coextensive layers with the production fluids floating

on sea water.

The semi-submersible production platform or barge may comprise a body which defines a plurality of said storage tanks, said legs being fixed to said body at a peripheral region of the body.

The body may be substantially rectangular and have a respective said leg connected therewith at each corner thereof.

Preferably, the semi-submersible production platform or barge has a storage capacity substantially in the range of 100,000 through 200,000 tonnes of production fluids.

The invention also includes a vessel equipped for storage of oil production fluids from an undersea reservoir, said vessel comprising storage tank means and a superstructure which is supported by downwardly extending leg means, said superstructure and leg means being connected together to form a buoyant structure and said storage tank means being fixed to the vessel such that, in use, the storage tank means is submerged below the sea surface, said storage tank means being provided with inlet baffles disposed, in use, near the tope of the storage tank means for diffusing and absorbing the kinetic energy of such oil production fluids received in the storage tank means.

In order that the invention may be well

understood some embodiments thereof, which are given by way of example only, will now be described with reference to the drawings, in which:

Figure 1 is a perspective view of a known semi-submersible for extracting production fluids from an undersea deposit or reservoir;

Figure 2 is a partial schematic view of a vessel according to the invention;

Figure 3 is a side view of the vessel shown in Figure 2 showing a storage tank, in use, filled with oil production fluids and sea water;

Figure 4 is a perspective view of a semi-submersible barge or loading unit according to the invention with a shuttle tanker berthed alongside; and

Figure 5 is a schematic diagram showing the position of the semi-submersible barge shown in Figure 5 and the mooring lines, risers and wellheads.

Referring to Figures 2 and 3, a vessel or semi-submersible 20 comprises a superstructure (not shown) and four legs 21 extending downwardly from the superstructure. A body 22 defining a plurality of storage tanks 25 is integrally fixed to the ends of the four legs 21 and in use is always filled with liquid namely: a) sea water only; b) oil production fluids only; or c) a liquid consisting of two separate substantially coextensive layers with such oil

production fluids floating on the sea water. The storage tanks 25 are located well below the surface of the sea and the effect of waves on the sides of the tank is negligible. Consequently the structure of the storage tanks can be much lighter than such tanks located above the sea water as wave pressure effects can be virtually eliminated and the walls of the tanks are supported from the outside by sea water. The storage tanks 25 have a potential storage capacity which is preferably in the range 100,000 - 200,000 tonnes of oil.

The body 22 is rectangular and is integrally connected at each corner thereof with a respective leg 21. The integral connection between the body and the legs is such that there is no need to provide additional structural members for interconnecting the lower ends of the legs.

The body 22 is divided by two substantially perpendicular partitions 23 which divide the body into four independent storage tanks 25 each having a flow port 24 for causing or allowing (i) admission of sea water during pumping out of oil production fluids stored in the respective storage tank and (ii) discharge of sea water during filling of the storage tank with oil production fluids. The partitions increase the strength and rigidity of the body 22.

A pump 26 is located in one of the legs 21 for pumping production fluids into or out of the storage tanks 25. In a preferred construction a pump unit may be provided in each leg servicing a respective storage tank.

The storage tanks are lined with an insulation material which prevents stored oil from being cooled by cold sea water. This can be very useful where the produced fluids are liable to solidify or become very viscous in cold conditions. Furthermore, the insulating layer can provide increased protection against oil leakages into the sea. An alternative construction of insulating layer can be achieved by surrounding the body 22 with a "coffer dam" which could then be lined with insulating material.

The vessel is constructed from square of rectangular box sections butt-welded together. This ship building type structure produces a strong and cost effective vessel. Furthermore, it eliminates the need to use circular cross-section legs and their complicated connecting sections at the corners.

In use, the storage tanks 25 are initially filled with sea water (first filled during construction on shore). When it is necessary to store oil in the tanks, the pump 26 is operated and oil production fluids are pumped from the well head and up the

risers. The oil production fluids enter the storage tanks (pr ferably from the top and via inlet baffles) and begin to displace the sea water in the tanks. As the density of the oil production fluids is slightly lower than that of sea water, the oil production fluids float on top of the sea water. Sea water is progressively displaced from the tank and is expelled from the tank via the flow port 24. As shown in Figure 3, in one use condition thereof, the storage tanks 25 are filled with a liquid consisting of two substantially co-extensive layers comprising a layer 26 of oil production fluids floating on a layer 28 of sea water.

A membrane (not shown) may be arranged in the tank to separate the oil and water, so that there is only indirect contact between the two liquids.

In practice, a small amount of sea water will remain in the bottom of the storage tanks, which will contain any oil contamination, and which can be transferred to the "dirty tanks" of the tanker and be taken to shore, or pumped downhole, or cleaned-up, after the oil has been discharged from the tank. Collection/monitoring means (not shown) may be provided to receive the displaced sea water and to monitor the presence of oil production fluids in the sea water, and which is operative to stop the pump as

soon as the tank is full of oil production fluids or if the sea water becomes contaminated. The expelled sea water may pass through a settling tank before reaching the open sea. This allows any globules of well fluid or oil in the water to settle out and be returned to the storage tanks. As the storage tanks are filled the overall weight of the vessel 20 decreases slightly and it starts to rise out of the water. In order to compensate for this rise in draft, sea water may be pumped into buoyancy tanks (not shown) located in each of the legs 21.

Figure 5 shows a shuttle tanker 50 berthed alongside a semi-submersible barge 51 according to the invention. The barge comprises a superstructure 52 with four legs 53 extending below the surface of the sea. A storage tank 54 (see Figure 6) is secured to the ends of the legs 53. The semi-submersible barge 51 is secured to the sea bed by mooring lines 55 and well fluids are carried to the surface from the well heads 56 via flexible or semi-rigid risers 57. Well fluids are stored in the tank 54 until transferred to a shuttle tanker 50 for transport to a shore-based destination.

CLAIMS:

1. A vessel equipped for storage of oil production fluids from an undersea reservoir, said vessel comprising storage tank means and a superstructure which is supported by downwardly extending leg means, said superstructure and leg means being connected together to form a buoyant structure and said storage tank means being fixed to the vessel such that, in use, the storage tank means is submerged below the sea surface, said storage tank means being provided with insulating means for reducing heat loss from oil production fluids stored therein.

2. A vessel as claimed in claim 1, wherein said storage tank means is lined with an insulating material.

3. A vessel equipped for storage of oil production fluids from an undersea reservoir, said vessel comprising at least one storage tank and a superstructure which is supported by a plurality of downwardly extending legs, said legs and superstructure being connected together to form a buoyant structure and the or each said storage tank being fixed to the vessel such that, in use, the or

each storage tank is submerged below the sea surface, the or each said storage tank being arranged to receive and discharge oil production fluids and sea water such that in one use condition thereof the storage tank is filled with a liquid consisting of two separate substantially co-extensive layers with such oil production fluids floating on sea water.

4. A vessel as claimed in claim 3, wherein the or each said storage tank is provided with inlet baffles disposed, in use, near the top of the storage tank, said inlet baffles being arranged to absorb the kinetic energy of such oil production fluids received in the storage tank and diffuse the oil production fluids thereby avoiding mixing of the two fluids.

5. A vessel as claimed in claim 3 or 4, wherein the or each said storage tank is provided with insulating means for reducing heat loss from oil production fluids stored therein.

6. A vessel as claimed in claim 5, wherein the or each said storage tank is lined with an insulating material.

7. A vessel as claimed in any one of claims 3 to 6,

wherein the or each said storage tank is fixed to the lower ends of said legs.

8. A vessel as claimed in claim 7, wherein the or each said storage tank is integrally connected to the lower ends of said legs.

9. A vessel as claimed in any one of claims 3 to 6, comprising a body defining a plurality of said storage tanks, said legs being connected with the body.

10. A vessel as claimed in claim 9, wherein said body is provided with two substantially perpendicular partitions which define four said storage tanks, each said storage tank being provided with a respective flow port for (i) admission of sea water during pumping out of oil production fluids stored therein and (ii) discharge of sea water during filling of the storage tank with oil production fluids.

11. A vessel as claimed in any one of the preceding claims, further comprising monitoring means for monitoring the presence of such oil production produced fluids in sea water expelled from the or each said storage tank during filling with such oil production fluids.

12. A vessel as claimed in claim 11, wherein said monitoring means comprises at least one settling tank for removing such oil production fluids from sea water when the latter fluid is discharged from the or each said storage tank.

13. A vessel as claimed in any one of the preceding claims, wherein said legs are provided with buoyancy tanks for allowing the buoyancy of the vessel to be altered.

14. A vessel as claimed in any one of the preceding claims, substantially constructed from square or rectangular box sections butt-welded together.

15. A vessel as claimed in any one of claims 3 to 14, wherein the or each said storage tank is provided with membrane means for separating said layers of oil production fluids and sea water.

16. A method of storing oil production fluids in an oil production vessel having a submerged storage tank fixed to buoyant support legs of the vessel, said method comprising (i) filling the submerged tank with sea water and (ii) pumping oil production fluids into the storage tank and causing or allowing sea water in

the storag tank to be discharged as said oil production fluids are pumped into the storage tank such that said oil production fluids, being of lower density than sea water, float as a layer on the sea water whereby the storage tank is filled by a liquid consisting of a layer of sea water and a separate substantially coextensive layer of oil production fluids.

17. A method as claimed in claim 16, wherein collection means is provided to receive sea water discharged from the storage tank and separate any oil production fluids present in the sea water prior to the sea water being expelled into the surrounding environment.

18. A method as claimed in claim 17, wherein said collection means comprises a settling tank which helps maintain separation of sea water and production fluids.

19. A method as claimed in claim 17 or 18, wherein separated oil production fluids are returned to the storage tank.

20. A method as claimed in any one of claims 16 to

19, further comprising the step of providing membrane means in said storage tank for separating said layers of oil production fluids and sea water.

21. A semi-submersible production platform comprising at least one storage tank for receiving and storing production fluids and a superstructure supported by a plurality of downwardly extending legs, said legs and superstructure being connected together to form a buoyant structure and the or each said storage tank being arranged to be submerged below the sea surface, in use, and being provided with at least one flow port for (i) admitting sea water into the storage tank to compensate for production fluids being discharged therefrom and (ii) for allowing sea water in the storage tank to be discharged during filling thereof with production fluids, whereby in one use condition thereof the or each said storage tank is filled with a liquid consisting of two separate substantially coextensive layers with the production fluids floating on sea water.

22. A semi-submersible barge comprising at least one storage tank for receiving and storing production fluids and a superstructure supported by a plurality of downwardly extending legs, said legs and said

superstructure being connected together to form a buoyant structure and the or each said storage tank being arranged to be submerged below the sea surface, in use, and being provided with at least one flow port for (i) admitting sea water into the storage tank to compensate for production fluids being discharged therefrom and (ii) for allowing sea water in the storage tank to be discharged during filling of the storage tank with production fluids, whereby in one use condition thereof the or each said storage tank is filled with a liquid consisting of two separate substantially coextensive layers with the production fluids floating on sea water.

23. A semi-submersible as claimed in claim 21 or 22, comprising a body which defines a plurality of said storage tanks, said legs being fixed to said body at a peripheral region of the body.

24. A semi-submersible as claimed in claim 23, wherein said body is substantially rectangular and a respective said leg is connected therewith at each corner of said body.

25. A semi-submersible as claimed in any one of claims 21 to 23, having a storage capacity

substantially in the range of 100,000 through 200,000 tonnes of production fluids.

26. A vessel equipped for storage of oil production fluids from an undersea reservoir, said vessel comprising storage tank means and a superstructure which is supported by downwardly extending leg means, said superstructure and leg means being connected together to form a buoyant structure and said storage tank means being fixed to the vessel such that, in use, the storage tank means is submerged below the sea surface, said storage tank means being provided with inlet baffles disposed, in use, near the tope of the storage tank means for diffusing and absorbing the kinetic energy of such oil production fluids received in the storage tank means.

27. A vessel substantially as hereinbefore described with reference to Figures 2 and 3 of the drawings or a semi-submersible barge substantially as hereinbefore described with reference to Figure 4 and 5 of the drawings.

28. A method of storing oil production fluids substantially as hereinbefore described with reference to Figures 2 and 5 of the drawings.

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Patents Act 1977 Examiner's report to the Comptroller under Section 17 (The Search report)	Application number GB 9523204.7
Relevant Technical Fields (i) UK Cl (Ed.N) B7A (AAAQ) (ii) Int Cl (Ed.6) B63B 35/44	Search Examiner A HABBIJAM Date of completion of Search 3 JANUARY 1996
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE: WPI	Documents considered relevant following a search in respect of Claims :- 1 & 2

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2017593 A	(OLAV MO) see tanks 8 surrounded by concrete Figure 2	1
X	GB 2017592 A	(LINDE AKTIENGESELLSCHAFT) see in particular page 3 lines 115-118 and Figures 1, 3 & 5	1
X	GB 2001012 A	(DYCKERHOFF & WIDMANN) see container 4 surrounded by concrete 5 in Figure 4	1
X	GB 1546976	(PREUSSAG) see page 3 lines 57-63 and Figures 1 & 2	1 & 2
X	GB 1233422	(SANTA FE INTERNATIONAL) see page 4 lines 15-19 and Figures 5 & 6	1 & 2

Databases:The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).

Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

Application number
GB 9523204.7

Continuation page

Category	Identity of document and relevant passages		Relevant to claim(s)
X	US 4202648	(KVAMSDAL) see tanks 15 surrounded by concrete insulation 1	1